PATENT SPECIFICATION

DRAWINGS ATTACHED

Inventor: BRIAN WILLIAM MANLEY

1,159,347

1,159,347

Date of filing Complete Specification: 6 June, 1968.

Application Date: 12 July, 1967. *No. 32016/67.*

Complete Specification Published: 23 July, 1969.

Index at acceptance: —**H1** D(4A1, 4A4, 4A2Y, 4A2X, 4K2, 4A2A, 4K3B, 4F2Y, 4F2B, 4F2C, 4F2E, 4F6Y, 4F6B, 15A, 18C, 34, 45A); **H4** F(D12M, D18K, D18X, D68, D25L, D26M, D40S); **H5** R7

Int. Cl.: —**H 01 j 31/49**

COMPLETE SPECIFICATION

Improvements in or relating to Image Intensifiers and the like

We, MULLARD LIMITED, of Abacus House, 33 Gutter Lane, London, E.C.2., A British Company. do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electronic image intensifier and like devices. More particularly the invention relates to "channel intensifier" devices and to electronic imaging tubes employing such devices. Such devices will be defined later but, briefly, they are secondary-emissive electron-multiplier devices comprising a matrix in the form of a plate having a large number of elongated channels passing through its thickness, said plate having a first conductive layer on its input face and a separate second conductive layer on its output face to act respectively as input and output electrodes.

Secondary-emissive intensifier devices of this character are described, for example, in Patent Specifications No. 1,064,073, No. 1,064,074, No. 1,064,076, No. 1,090,406 and No. . . . . .. (co-pending Application 22339/67;) (Serial No. 1,154,515), while methods of manufacture are described in Patent Specifications No. 1,064,072 and No. 1,064,075.

In the operation of all these intensifier devices (when incorporated in electronic imaging tubes) a potential difference is applied between two electrode layers of the matrix so as to set up an electric field to accelerate the electrons, which field establishes a potential gradient created by current flowing through resistive surfaces formed inside the channels or (if such channel surfaces are absent) through the bulk material of the matrix. Secondary-emissive multiplication takes place in the channels and the output electrons may be acted upon by a further accelerating field which may be set up between the output electrode and a suitable target, for example a luminescent display screen.

As a summary of this art, the structure of the devices referred to herein as "channel intensifier" devices (or, more briefly, "channel plates") is defined in the Patent Specifications referred to above in a definition given in the following terms:

A channel intensifier device is a secondary-emissive electron multiplier device for an electronic imaging tube which device comprises a resistive matrix in the form of a plate the major surfaces of which constitute the input and output faces of the matrix, a conductive layer on the input face of the matrix serving as an input electrode, a separate conductive layer on the output face of the matrix serving as an output electrode, and elongated channels each providing a passageway from one face of the assembly consisting of matrix and input and output electrodes to the other face of said assembly.

It is an object of the present invention to employ a channel intensifier device for detecting particles or radiation quanta and determining the distribution thereof over a given area. Such distribution may, in some cases, be sufficiently complex to represent a crude form of imaging in which the definition and the number of picture elements are very low as compared with imaging applications of the broadcast television type. The invention is also applicable in cases where, from a low particle rate (defined below), a picture of

[*Price* 4*s.* 6*d.*]

fairly high definition can be built up gradually with the aid of additional storage means, for example gamma radiography for medical purposes.

The invention provides a particle or radiation quantum detector system comprising a channel intensifier device as defined above wherein the output electrode is substantially planar and is subdivided into an array of parallel electrode conductors with each conductor connected to a separate terminal, an array of target conductors lying substantially in a plane parallel to the plane of said electrode conductors on the output side of each device which target conductors are parallel to each other and orientated at, or approximately at right angles to the direction of the electrode conductors, and a second set of terminals each of which appertains to one of said target conductors.

In such an arrangement the array of electrode conductors replaces the more normal form of output electrode which is usually (but not always) described in the above prior Specifications as a single electrically continuous layer. Similarly, the present array of target conductors replaces the continuous conductive target layer which is more usually provided on a phosphor screen on the output side of a channel intensifier device.

A particle or radiation quantum detector system according to the invention can be combined with an output circuit arrangement comprising a separate charge detector for each electrode conductor and a separate charge detector for each target conductor, and means whereby each event causes a simultaneous response in one of the electrode detectors and in one of the target detectors so as to provide, together, a co-ordinate position for the event. This mode of operation is suitable for applications in which there is a low particle or quantum rate, i.e. there are so few events that the chance of two simultaneous events can be ignored. If the rate is higher, means can be provided (as will be described) to inhibit the system when ambiguities arise as to the number and position of events:— for example, two simultaneous events which are spaced apart in both the X and Y directions will identify four (instead of two) electrode intersections between two electrode conductors and two target conductors (it is convenient to use the term "intersection" even though the two arrays of conductors are spaced apart).

In addition to the individual charge detectors it may in some cases be desirable to provide one general discriminator either in a common supply circuit of the target detectors or in that of the electrode detectors for purposes such as determining whether the magnitude of an event is greater or smaller than a given datum.

The target conductors may or may not be associated with luminescent elements to provide a two-dimensional visual display of the positions of detected particles in addition to the counting and/or recording action of the circuit actuated by the output signals. If this is done, the luminescent elements may or may not form a continuous phosphor screen and they may be provided on the side of the target array remote from the channel plate (if so, the array can be in the form of aluminium backing strips).

Embodiments of the invention will now be described by way of example with reference to Figs. 1 to 4 of the diagrammatic drawings accompanying the Provisional Specification and Fig. 5 of the accompanying drawing.

Figure 1 shows schematically a system according to the present invention arranged within an evacuated envelope as a tube comprising a channel intensifier device I together with a target system Ta—Tn. The channel intensifier device I includes an input electrode E1 covering its input face and an output electrode comprised of an array of parallel electrode conductors in the form of strips E2a, E2b . . . E2n. Each of the latter is connected through a separate charge detector or amplifier to a common supply source shown schematically at B1, but for simplicity all these electrode detectors are shown as a combined electrode detector system ED.

In some applications input radiation can be imaged on to the device I of Figure 1 by an optical system and the system may require a photocathode on the input side of the channel plate I either in contact therewith or spaced therefrom as described in the aforesaid prior Specifications.

By contrast, in diagnostic X-ray radiography or gamma-ray auto-radiography it may not be necessary to use a photocathode since gamma or X-ray photons can cause electron emission from the material of the matrix which is usually made of a suitable glass or combination of glasses. Moreover, optical systems are not used in these applications and for this reason the body to be examined is usually placed as close to the channel intensifier device as is practicable, and this is indicated schematically at B in Figure 1. As an example of this, in the case of gamma-ray radiography, the body B which is to be examined can be placed as close as possible to the device I and emits a pattern of gamma radiation via a lead matrix collimator (not shown) on to the input face of the device I. Whenever a gamma particle enters the material of the channel plate, one or more electrons may be produced and may escape into a channel. Then electron multiplication can take place in the manner described in the aforesaid prior Patent Specifications, and a pulse of secondary electrons will emerge from the output end of the said channel and in so doing will provide an

output signal in the detector corresponding to the particular electrode strip.

Figure 1 can also be taken as illustrating the case in which the input radiation is constituted by X-rays irradiating the body B from a point source (not shown). In conclusion, Figure 1 can be taken as illustrating both this case and also the use of gamma rays directed from the body B to the channel plate via a lead collimator.

The target is constituted by a set of parallel target conductors Ta, Tb . . . Tn which lie in a direction which is at, or approximately at, right angles in the direction of the electrode strips, for example in a vertical direction if the electrode strips E2a, E2b . . . E2n are horizontal. These target conductors are also each connected to a separate charge detector or amplifier, but said detectors are all shown for simplicity as a combined target detector system TD connected to a common source of accelerating potential represented schematically at B2.

Although it is not essential to have an extremely regular disposition of the channels in the channel plate nor to have an extremely accurate registration between individual output electrode conductors and the individual channels, it is possible to have one row of channels corresponding to each one of the electrode strips as shown in Figure 2. Alternatively it is possible to have more than one row of channels corresponding to one electrode strip, or just a statistically uniform band of channels covered by each electrode strip if the channel structure is materially finer than the desired resolution.

The arrangement of Figure 1 is shown more clearly in Figure 3 where, for the sake of clarity, only a very small number of electrode conductors and target conductors is shown, namely four of each. Also for the sake of clarity the electrode conductors are shown arranged as in Fig. 2 although they may be arranged in other ways as mentioned above. As will be seen, each of the electrode conductors is a strip E2a—E2d connected through a separate charge detector EDa—EDd. Similarly each of the target conductors Ta—Td is a strip connected through a separate charge detector TDa—TDd. If a particle enters a particular channel Cx it will cause an output of secondary electrons as shown and it will also cause an output signal in the electrode detector EDa and also an output signal in the target detector TDc. These two signals, if collated will give the position of the event in channel Cx as a pair of co-ordinates.

This collation can be carried out e.g. with the aid of a ferrite core store which can be used as the source of information from which a C.R.T. display can be generated.

Alternatively the collated co-ordinate information can be directly fed to a cathode-ray storage tube in order to build up therein and display the information.

Both these arrangements are illustrated schematically in Figure 4 where the unit M may be a ferrite core store with read-out means connected to a conventional C.R.T. display tube. For the alternative arrangement, the unit M can be ferrite core matrix used only for collation while the C.R.T. is a display tube of the storage type.

A further circuit arrangement is shown in greater detail in Fig. 5 of the accompanying drawing and will now be described, the arrangement including inhibiting means of the kind referred to previously.

The charge detectors are constituted by the stages of two shift registers. When a pulse of charge is registered on both horizontal and vertical arrays, a digit is stored in each shift register in the stages corresponding to the row position and column position of the event. The read-out process then entails the shifting of the contents of the registers to the right in such manner as to simulate line and frame scanning. Thus in each register position of the column register it is necessary to cycle completely the row register. Therefore the shift pulses to the column register occur with a frequency a factor n lower than the row shift pulses (n is equal to the number of rows) and the cycling continues until the stored digits appear at the right hand end of the registers at the same instant. A bright-up pulse is then produced on the writing beam control of an integrating storage display tube which is being scanned in synchronism with the register shifts. In detail the operation is as follows.

Charge emerging from a channel and striking a target (or column) strip will produce a pulse of charge in that strip and also in the electrode (or row) strip containing the channel. These pulses will be similar in magnitude but opposite in sign since one is due to electrons leaving and the other is due to electrons arriving. The purpose of exclusive—OR 1 and exclusive—OR 2 is to ensure that there is only one pulse of charge from the rows and one from the columns. In the event of these being either no pulse from one of the sets of strips, or more than one from one or both sets, AND-gate 3 produces no output and AND-gate 4 does not produce a start pulse. Thus the unwanted signal is ignored. This is to guard against spurious events and to inhibit the system against two simultaneous events which the system cannot analyse unambiguously.

In the event that there is only one row pulse and one column pulse, the analysis proceeds as follows. The column pulse produces a pulse from exclusive—OR gate 5 which results in a start pulse from AND-gate 4. This pulse acts via unit 6 (a J—K flip-flop) to open the switch 7 so preventing further

pulses (arriving during the analysis of the present pulse) from producing disturbing signals. The start pulse is also fed into AND-gate 8 and thereby results in a sequence of clock pulses to the shift registers, so cycling them until each produces an output pulse into AND-gate 9, when a bright-up gating pulse is produced on the writing gun of the storage c.r.t. In addition, a stop pulse goes to the unit 6, so stopping the register cycling process and clearing the registers, and closing the switch 7 to await the next signal pulse (Flip-flop 6 is of the known bistable J—K type having always '0' at one output and '1' at its other output, these outputs being reversed when the unit changes state).

The synchronized operation of the scan generator is ensured by a frame-trigger and line-sync (FL) unit 11 which is controlled by clock pulses which have been divided by n in the divided unit 10.

In space applications it may not be desirable to have an evacuated envelope for the channel plate and target system as shown in Figure 1, and therefore the electrode and target conductor terminals, referred to throughout this Specification, may be circuit connections or connectors rather than terminals formed in the wall of a tube.

WHAT WE CLAIM IS:—

1. A particle or radiation quantum detector system comprising a channel intensifier device as defined above wherein the output electrode is substantially planar and is subdivided into an array of parallel electrode conductors with each conductor connected to a separate terminal, an array of target conductors lying substantially in a plane parallel to the plane of said electrode conductors on the output side of said device which target conductors are parallel to each other and orientated at, or approximately at, right angles to the direction of the electrode conductors, and a second set of terminals each of which appertains to one of said target conductors.

2. A detector system as claimed in Claim 1 when contained in an evacuated envelope with the electrode conductor terminals and the target conductor terminals secured on said envelope.

3. A detector system as claimed in Claim 1 or Claim 2 wherein the target conductors are associated with luminescent elements to provide a two-dimensional visual display of the positions of detected particles.

4. A detector system substantially as described with reference to Figures 1 and 3 or Figures 1 to 3 of the drawings accompanying the Provisional Specification.

5. A detector system as claimed in any of the preceding Claims when combined with an output circuit arrangement comprising a separate charge detector for each electrode conductor and a separate charge detector for each target conductor, and means whereby each event causes a simultaneous response in one of the electrode detectors and in one of the target detectors so as to provide, together, a co-ordinate position for the event.

6. A combination as claimed in Claim 5 including means for inhibiting the system whenever two or more events occur simultaneously at different coordinate positions.

7. A combination as claimed in Claim 5 or Claim 6 substantially as described with reference to Figure 4 of the drawings accompanying the Provisional Specification or Fig. 5 of the accompanying drawing.

G. V. CARCASSON,
Chartered Patent Agent,
Mullard House,
Torrington Place,
London, W.C.1.,
Agent for the Applicants.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1969.
Published by the Patent Office, 25, Southampton Buildings, London, W.C.2. from which copies may be obtained

FIG. 1.

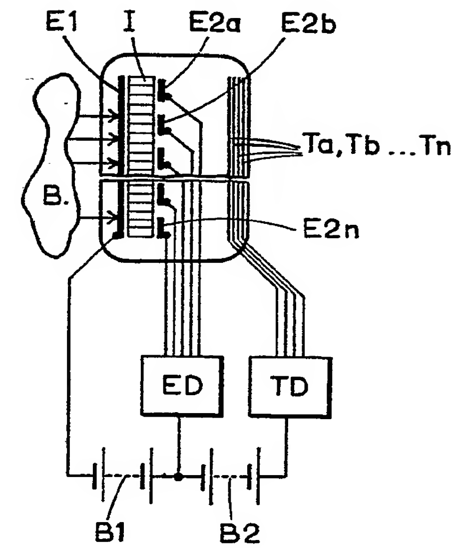
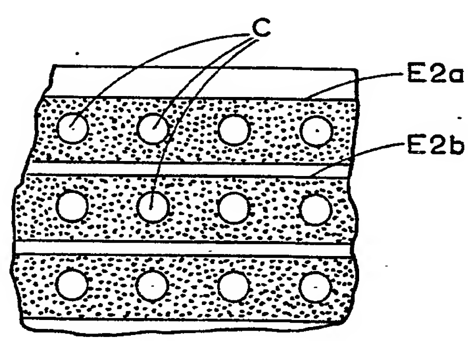


FIG. 2.



1159347 PROVISIONAL SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 2

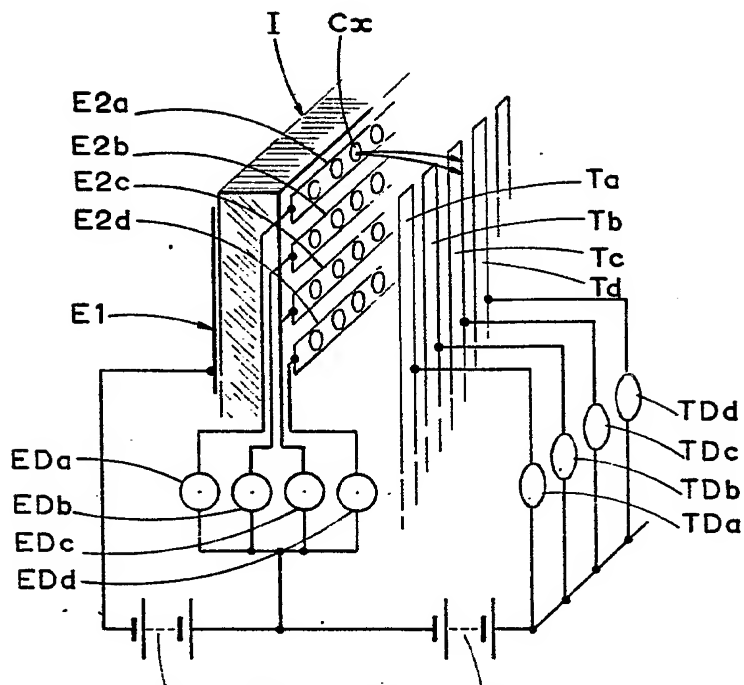


FIG.3.

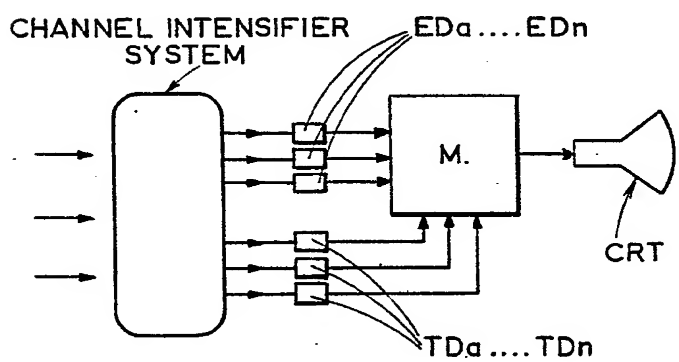


FIG.4.

1159347 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

FIG.5.